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TRAPPING OF WATER VAPOR FROM AN ATMOSPHERE BY CONDENSED SILICATE
MATTER FORMED BY HIGH-TEMPERATURE PULSE VAPORIZATION.

M.V.Gerasimov (1), Yu.P.Dikov (2), O.I.Yakovlev (3), F.Wlotzka (4).
Russian Academy of Sciences: 1 - Space Research Institute, 2 - Institute
of Ore Deposits Geology, Petrography, Mineralogy and Geochemistry, 3 -
Vernadsky Institute of Geochemistry and Analytical Chemistry; Moscow,
Russia. 4- Max-Planck-Institut für Chemie, Mainz, Germany.

The origin of planetary atmospheres is thought to be the result of bombardment of a growing planet by massive planetesimals. According to some models, the accumulation of released water vapor and/or carbon dioxide can result in the formation of a dense and hot primordial atmosphere [1,2,3]. Among source and sink processes of atmospheric water vapor the formation of hydroxides was considered mainly as rehydration of dehydrated minerals (forsterite and enstatite [2]). From our point of view, the formation of hydroxides is not limited to rehydration. Condensation of small silicate particles in a spreading vapor cloud and their interaction with a wet atmosphere can also result in the origin of hydrated phases which have no genetic connections with initial water bearing minerals. Here we present results of two experiments of a simulated interaction of condensed silicate matter which originated during vaporization of dry clinopyroxene (Na- 1.95, Mg- 7.13, Al- 4.29, Si-18.00, Ca- 6.05, Ti- 0.31, Fe- 2.51 at.%) in a wet helium atmosphere.

As in our previous experiments [4,5,6] vaporization was provided by use of laser pulses of a powerful neodymium laser focused on a sample which was mounted in a hermetic cell with a volume $\sim 500 \text{ cm}^3$. Parameters of the pulse are: luminous energy $\sim 600 \text{ J}$, duration $\sim 10^{-3} \text{ s}$, density of luminosity $\sim 5 \times 10^6 \text{ W/cm}^2$. Estimated temperature of vaporization is 3000-4000 K. The cell was continuously flushed with wet He at a rate $\sim 50 \text{ cm}^3/\text{min}$. In the first experiment water vapor was saturated at 22 C and in the second at $\sim 100 \text{ C}$, what corresponded to about 20 mbar and 1 atm. partial water vapor pressure. A noticeable amount of condensed particles with dimensions from 50 to 1000 Å originated in a spreading hot cloud [5] which interacted with the ambient atmosphere inside the cell. A certain amount of condensed material was collected on a filter which was placed at an outlet of the cell. Another part of the condensate was collected on a Ni-foil which was placed 8 cm from the sample on the path of the spreading vapor cloud. Chemical analyses of condensate was made using X-ray photoelectron spectroscopy (XPS) which provided both analyses of chemical composition and of chemical structure of the condensate. The condensate from the filter was analyzed by XPS and by transmitted electron microscopy (TEM) technic. The concentration of hydrogen was calculated from the sum of hydroxide bonds of the elements. Comparison of the amount of hydroxide groups calculated from the sum of phases of elements and from the spectral line of oxygen gives a good correlation.

XPS analyses reveal the formation of hydroxide bonds in the condensed silicates with practically all rockforming elements except Ca. Mg forms hydroxide bonds the most effectively providing $\sim 60\%$ of all hydroxides. About 20% of hydroxides are formed by Si and Al respectively.

Despite the large difference in partial pressure of water vapor in the two experiments the concentration of hydroxides in condensed films is practically the same in both cases. Concentration of trapped water in the bottom layers of condensed film is 10-12 wt.% and in the upper layers is 4-6 wt.%. While the front parts of the spreading vapor cloud are condensing

on the film in the bottom layers, the formation of hydroxides in the front compressed part of the vapor cloud interacting with wet atmosphere seems more effective than in the back parts of the cloud. XPS analyses of the condensate which was collected on the filter shows its identity with condensate in the upper layers of the condensed film. TEM analyses shows the presence of particles with crystal structure.

The results of these experiments are interesting to compare with results of our previous experiments in which the same sample of clinopyroxene was evapo-rated in a dry helium atmosphere and the same analytical procedure was applied to the condensed film [5]. An important difference between this two sets of experiments is the presence of noticeable amounts of reduced forms of elements (~9% of silicon in the form of Si^0 and Si^{2+} , ~15% and ~7% of metallic Al and Fe integrated through the volume of the film) in the dry experiment and their absence in experiment with water vapor. The absence of reduced forms of elements in the wet experiment demonstrates the oxidizing role of water molecules in the vapor cloud. The ratio of $\text{Fe}^{3+}/\text{Fe}^{2+}$ is noticeably higher in the experiment with saturation of water vapor at 100 C compared with the experiment at room temperature. This observation also reveals the role of water as oxidizing component in the vapor cloud. In the dry experiment the condensed film was exposed to open air for some hours before XPS analyses and could interact with atmospheric water vapor. No detectable hydroxide phases were formed during this period. This suggests that the formation of hydroxides occurs at higher temperature conditions but probably not higher than dehydration temperature.

Another important result proving the trapping of water vapor during impact processes is the discovery of hydroxide phases in the condensed film which was produced in light-gas-gun shock experiment with serpentinite target and copper projectile ($v_{\text{imp}} \sim 5.89 \text{ km/s}$) [7]. The condensate in this experiment was collected on special screens at a distance of 7-10 cm from the center of impact. Shock experiment was performed in air at 30 mbar pressure. Water vapor was injected inside the vapor cloud as a result of the dehydration of the serpentinite target. Analyses of condensed film shows uniform concentration of hydroxides through the depth of the film. Trapped water amounts to ~10 wt.% of the condensate. About 60% of Mg and 9% of Si is present as hydroxides.

These experimental results prove the possibility of effective trapping of water vapor from an atmosphere by dispersed hot silicate condensed matter. The experiment shows that trapped water can amount to ~10 wt.% of condensate mass even at rather low water vapor pressure in the atmosphere. The effectivity of the hydration process shows that it must be taken into account in evolutionary models of atmosphere formation.

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